



(11) **EP 1 043 557 A2**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
11.10.2000 Bulletin 2000/41

(51) Int. Cl.⁷: **F25J 3/04**

(21) Application number: 00201097.3

(22) Date of filing: 24.03.2000

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 09.04.1999 US 289286
20.12.1999 US 466972

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(54) Integrated air separation plant and power generation system

(57) In an air separation plant (1) integrated with another process, work is recovered from a nitrogen enriched stream (3) produced by an air separation process either by expanding the nitrogen enriched stream directly in a turbine (21,150) or by combustion of the nitrogen enriched stream with a fuel stream and expanding gas produced by the combustion. The work produced by the expansion is maximised by mixing the nitrogen enriched stream before the expansion step with a further gas stream (5,31) which may be air or may contain at least 2mol.% oxygen and/or at least 2mol.% argon and/or at least 10mol% carbon dioxide.

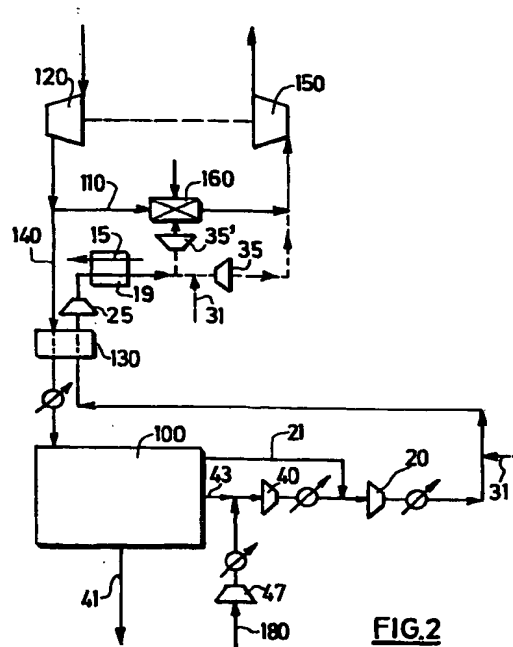


FIG.2

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Description

[0001] This invention relates to an air separation plant and an air separation process integrated with another process. It also relates to an integrated power generation system and process involving an air separation process. Work is recovered from the nitrogen enriched stream produced by the air separation either by expanding the nitrogen enriched stream directly or by combustion of the nitrogen enriched stream with a fuel stream and expanding gas produced by the combustion. The present invention is particularly related to an integrated power generation system process and apparatus in which a nitrogen enriched stream from an air separation unit is sent to a point upstream of the expander of a gas turbine.

[0002] Such integrated systems are well known. For example, EP-A-0622535 discloses an integrated power generation system in which nitrogen from an air separation unit is mixed with air and the mixture is sent to the compressor of a gas turbine and subsequently to the combustor. The nitrogen is cooled by expansion or addition of water before the mixing step to increase the gas throughput in the compressor.

[0003] EP-A-0538118 describes mixing nitrogen and compressed air from the air compressor before sending the mixture to the combustor of a gas turbine.

[0004] In US-A-5,076,837, a nitrogen stream is heated using a waste gas stream before being expanded in a turbine. The waste gas stream is produced by a chemical process using oxygen from the air separation unit.

[0005] EP-A-0225864 uses combustion gases to preheat nitrogen from an adsorption process before expanding the nitrogen in a turbine.

[0006] US-A-4,785,621 discloses an air compressor which produces two air streams, one of which is sent to an air separation unit. The other air stream is mixed with the nitrogen produced by the air separation, warmed using waste heat from a fired gas turbine and subsequently expanded in a turbine.

[0007] JP-A-57183529 and JP-A-57083636 describe a coal gasification power plant in which nitrogen from an air separation unit is mixed with air, compressed and sent to a combustor to produce combustion gas.

[0008] In US-A-3,731,495 air from a gas turbine compressor is divided in three. One part feeds an air separation unit producing impure nitrogen, one part is sent to the combustor and the rest is mixed with the gases from the combustor and the impure nitrogen at a temperature of about 1350°F.

[0009] US-A-4,557,735 shows a similar arrangement in which nitrogen which has served to regenerate the adsorbent beds is sent to the combustor of a gas turbine. In this case, an air stream is mixed with the compressed nitrogen and sent to the combustor.

[0010] EP-A-0568431 describes an air separation

unit producing oxygen, argon and krypton/xenon which is integrated with a gas turbine.

[0011] According to one aspect of the invention there is provided an integrated air separation apparatus comprising an air separation unit; means for sending air to the air separation unit, means for sending a nitrogen-enriched gas stream from the air separation unit to a point upstream of an expander, and means for sending at least one further gas which is air or which contains at least 2 mol.% oxygen, preferably at least 25 mol.% oxygen, and/or at least 2mol.% argon and/or at least 10mol.% carbon dioxide and/or at least 70% nitrogen to the nitrogen-enriched gas stream at a point upstream of the expander, means for mixing the at least one further gas with the nitrogen enriched stream from the air separation unit at a mixing point to form a gaseous mixture and means for sending the mixture upstream of the expander.

[0012] The apparatus may additionally comprise:

- a heat exchanger, means for sending air to the heat exchanger, means for sending air from the heat exchanger to the air separation unit, means for sending the nitrogen-enriched gas stream from the air separation unit to the heat exchanger, means for sending nitrogen enriched stream from the heat exchanger to a point upstream of the expander, and means for sending the at least one further gas to the nitrogen-enriched gas stream at a point upstream or downstream of the heat exchanger;
- means for sending the gaseous mixture to the input of the expander;
- an expander which is a turbine;
- means for sending the gaseous mixture to an input of a combustor upstream of a gas turbine expander and means for sending the combustion gases from the combustor to the expander;
- means for adding fuel to the gaseous mixture upstream of the combustor;
- a compressor for supplying air to the air separation unit and/or to the combustor;
- respective compressors for compressing air for the combustor and the air separation unit;
- means for warming the nitrogen enriched stream, preferably upstream or downstream of the mixing point;
- means for warming the nitrogen enriched stream which comprise a heat exchanger, and means for sending a gaseous product or waste stream from a plant in which an exothermic process takes place and at least the nitrogen enriched stream to the heat exchanger;
- means for feeding a gas or liquid produced by the air separation plant or compressed air from a compressor of the installation to the plant in which the exothermic process takes place;
- means for feeding a fluid from the air separation unit to a plant from which the further gas is derived;

- means for sending an oxygen enriched stream (9) from the air separation unit to a reformer (29) and means for deriving a carbon dioxide enriched stream (5) from a gas produced by the reformer and means for sending the carbon dioxide enriched gas to the nitrogen stream;
- means for sending the at least one further gas (5, 24) which is air or which contains at least 2mol.% oxygen and/or at least 2mol.% argon and/or at least 10mol. % carbon dioxide from the air separation unit (1) to the nitrogen enriched stream.

[0013] According to the invention, there is further provided an integrated power generation system apparatus comprising an air separation unit producing at least one nitrogen-enriched gas stream, a gas turbine comprising a combustor and an expander, means for sending air to the combustor and to the air separation unit and means for sending a mixture comprising the nitrogen-enriched gas stream from the air separation unit and air to a point upstream of the expander wherein the air mixed with the nitrogen enriched stream comes from a source other than the means for sending air to the combustor and to the air separation unit.

[0014] According to the invention, there is further provided an integrated power generation system apparatus comprising an air separation unit producing a nitrogen-enriched gas stream, a gas turbine comprising a combustor and an expander, a heat exchanger for cooling air by indirect heat exchange with cooling water, means for sending cooled air to the air separation unit, and means for removing at least first and second nitrogen-enriched gas streams from the air separation unit, a cooling tower for placing in direct contact the first nitrogen enriched gas stream and the cooling water upstream of the heat exchanger, means for removing a humidified nitrogen enriched stream from the cooling tower, a compressor for compressing the humidified nitrogen enriched stream and means for sending the humidified nitrogen-enriched gas stream from the compressor unit to a point upstream of the expander.

[0015] Optionally:

- the compressed humidified nitrogen-enriched stream is mixed with the second nitrogen-enriched stream (12);
- the first nitrogen-enriched stream does not regenerate the purification system of the air separation unit before being sent to the cooling tower.

[0016] According to a further aspect of the invention, there is provided a power generation system comprising an air separation unit, means for sending air to the air separation unit, means for removing a nitrogen enriched stream from the air separation unit and heating it to a temperature above 600°C, means for sending the heated gas to the combustion chamber of a gas turbine or upstream of the expander of a gas turbine.

[0017] Optionally the system comprises:

- means for compressing the nitrogen enriched stream, preferably to a pressure between 30 and 100 bars upstream the heating means;
- means for sending a fluid from the air separation unit to a unit which produces a hot gas stream and means for sending at least part of the hot gas stream to the heating means so as to heat the nitrogen enriched gas;
- means for mixing the nitrogen enriched gas with another gas upstream of the heating means (19);
- means for expanding the heated nitrogen enriched gas stream upstream of the combustion chamber or of the expander.

[0018] According to a further aspect of the invention, there is provided an integrated air separation process using an air separation unit and an expander, comprising the steps of sending air to the air separation unit, sending a nitrogen enriched stream from the air separation unit to a point upstream of the expander, and sending at least one further gas stream other than a fuel stream to a point upstream of the expander to form a mixture

[0019] At least one further gas may be air.

[0020] At least one further gas may contain at least 2mol.% oxygen, preferably 25 mol.% oxygen and/or at least 2mol.% argon and/or at least 10mol.% carbon dioxide.

[0021] At least one further gas (5,24,108) may contain at least 70mol.% oxygen and/or at least 30mol.% argon and/or at least 90mol.% carbon dioxide.

[0022] At least one further gas may contain at least 80mol.% oxygen or at least 80mol.% argon or at least 95mol.% carbon dioxide.

[0023] Optional features of the process include:

- mixing the further gas with the nitrogen enriched stream from the air separation unit to form a gaseous mixture;
- sending the gaseous mixture to the input of the expander;
- sending the gaseous mixture to the input of a combustor of an expander of a gas turbine;
- removing said further gas comprising at least 25 mol.-% oxygen and/or at least 2mol.% argon and/or at least 10% carbon dioxide from the air separation unit;
- warming the enriched nitrogen stream either before or after the mixing step to a temperature of at least ambient temperature before being sent to the point upstream of the expander by indirect heat exchange with a gaseous stream which is a product or a waste stream;
- producing the gaseous stream by a unit fed by an oxygen-enriched stream or a nitrogen enriched stream or an argon enriched stream from the air

separation unit or by a compressed air stream from a compressor which also feeds air to the air separation unit.

[0024] According to a further aspect of the invention, there is provided an integrated power generation process comprising cooling air by indirect heat exchange with cooling water in a heat exchanger, sending cooled air to the air separation unit, separating the air in the air separation unit, removing at least a first nitrogen-enriched gas stream from the air separation unit, placing in direct contact in a cooling tower the first nitrogen enriched gas stream and the cooling water to be sent to the heat exchanger, removing a humidified nitrogen enriched stream from the cooling tower, compressing the humidified nitrogen enriched stream in a compressor unit, sending the humidified nitrogen-enriched gas stream from the compressor unit to a point upstream of an expander of a gas turbine, sending an oxygen containing fluid and/or fuel to a combustor of the gas turbine to produce combustion gases and sending combustion gases from the combustor to be expanded in the expander.

[0025] The humidified nitrogen gas may be warmed to a temperature of at least 200°C, preferably at least 600°C before being sent to the expander or the combustor. It may also optionally be mixed with another gas enriched in a component of air (nitrogen, oxygen or argon) or carbon dioxide.

[0026] According to a further aspect of the invention, there is provided an integrated power generation process comprising sending air to an air separation unit, removing a nitrogen-enriched stream from the air separation unit, heating the nitrogen enriched stream to at least 600°C by indirect heat exchange in a heat exchanger and sending the heated nitrogen enriched stream either to the combustion chamber of a gas turbine or upstream of the expander of a gas turbine.

[0027] Optionally:

- the nitrogen enriched stream is expanded between the heating step and the combustion chamber or the inlet of the expander;
- the nitrogen enriched stream is compressed to a pressure between 30 and 100 bars upstream of the heat exchanger;
- the nitrogen enriched stream is mixed with another stream upstream or downstream of the heat exchanger.

[0028] According to a further aspect of the invention, there is provided an integrated power generation system apparatus comprising an air separation unit, a gas turbine comprising a combustor and an expander, a first compressor, means for sending air from the first compressor to the combustor and to the air separation unit, means for sending a nitrogen enriched stream from the air separation unit to a point upstream of the

expander, and means for sending a further gas enriched in a component chosen from the group comprising oxygen, argon and carbon dioxide to a point upstream of the expander.

[0029] Further optional features of the invention include means for mixing the further gas with the nitrogen enriched stream from the air separation unit to form a gaseous mixture, means for sending the gaseous mixture to the input of the expander or means for sending the gaseous mixture to the input of the combustor.

[0030] In particular, the apparatus may comprise means for feeding a fluid from the air separation unit to a plant from which the further gas is derived.

[0031] The example shows means for sending oxygen from the air separation unit to a reformer and means for deriving a carbon dioxide enriched stream from the synthesis gas produced by the reformer. The carbon dioxide enriched stream is then mixed with the nitrogen enriched stream and heated using the synthesis gas or another gas before being expanded.

[0032] According to a further aspect of the invention, there is provided an integrated power generation system apparatus comprising an air separation unit producing gaseous nitrogen enriched stream, a gas turbine comprising a combustor and an expander, means for sending air to the combustor and to the air separation unit, means for mixing gaseous nitrogen enriched stream from the air separation unit and air, means for warming the air and nitrogen enriched stream mixture by indirect heat exchange and means for sending the warmed mixture of air and nitrogen enriched stream from the air separation unit to a point upstream of the expander.

[0033] According to a still further aspect of the invention, there is provided a process for generating power using an integrated power generation system apparatus having an air separation unit, a gas turbine comprising a combustor and an expander, comprising the steps of sending air to the combustor and to the air separation unit, sending nitrogen enriched stream from the air separation unit to a point upstream of the expander, and sending a further gas enriched in a component chosen from the group comprising nitrogen, argon and carbon dioxide to a point upstream of the expander.

[0034] Optional features of this process include mixing the further gas with the nitrogen from the air separation unit to form a gaseous mixture, sending the gaseous mixture to the input of the expander or sending the gaseous mixture to the input of the combustor.

[0035] According to a still further aspect of the invention, there is provided a process in which air is separated to produce at least a nitrogen-enriched stream, comprising the steps of mixing the nitrogen-enriched stream with a stream of compressed air to form an enriched nitrogen air stream, warming the enriched nitrogen air stream by indirect heat exchange, sending air and a fuel gas stream to a combustor to

generate a combustion stream, expanding the combustion stream in an expander, and sending the enriched nitrogen air stream to a point upstream of the expander.

[0036] In particular, the process may be an integrated gasification combined cycle process in which oxygen from the air separation unit is sent to gasify a carbon containing substance thereby producing fuel for the combustor.

The invention will now be described in more detail with reference to the following figures:

Figures 1,2,3,4,5 and 6 are schematic diagrams of six embodiments of the process of the present invention.

[0037] Figure 1 shows the case where nitrogen is mixed with air to form a nitrogen-enriched air stream; the mixture is then warmed and sent to a point upstream of the expander.

[0038] Air is compressed in a compressor 120 of a gas turbine. Part of the air 110 is sent to the combustor 160 and the rest 140 is sent to an air separation unit 100. The air separation unit may also receive air from another independent compressor (not shown).

[0039] The air separation unit is typically a cryogenic distillation unit comprising at least two thermally linked columns containing trays or structured packings. It may additionally comprise an argon separation column fed from one of the other columns or from the other column. Alternatively, it may simply comprise a single column.

[0040] The air separation unit 100 in the case illustrated produces oxygen enriched stream 41 which may, for example, be sent to a coal gasification unit (not shown) and nitrogen enriched streams 21, 43 at two different pressures. An air stream 180 from compressor 47 is optionally mixed with the low pressure nitrogen enriched stream 43, compressed in compressor 40, mixed with the high pressure nitrogen enriched stream 21 and further compressed in compressor 20. It is subsequently warmed in heat exchanger 130 against feed air 140 which is cooled in the heat exchanger 130 before cooling within the air separation unit 100 to a temperature suitable for distillation.

[0041] The air stream may alternatively be mixed with the nitrogen enriched stream downstream of compressor 40 or compressor 20.

[0042] The mixed stream is then sent to the combustor 160 with the fuel stream. The combustion gases are sent to the expander and are used to generate electricity or drive a compressor.

[0043] The mixed stream may alternatively be sent to the input of the expander as shown in dashed line in Figure 1.

[0044] Alternatively the air may be mixed with the nitrogen enriched stream downstream of the warming step.

[0045] It may be advantageous to heat the nitrogen

enriched stream /air mixture in heat exchanger 19 downstream of heat exchanger 130 by heat exchange with a hot gaseous stream 15 as will be described in further detail below.

[0046] In all cases, the air stream may be replaced by a gaseous stream containing at least 50mol.-% of gaseous oxygen, argon or carbon dioxide or another gas which may be expanded safely in the turbine, preferably at least 60mol.-% of gaseous oxygen, argon or carbon dioxide, more preferably at least 70mol.-% of gaseous oxygen, argon or carbon dioxide and still more preferably at least 80mol.-% of gaseous oxygen, argon or carbon dioxide, for example an impure oxygen stream, an argon stream, a carbon dioxide stream.

[0047] In this way, it is possible to make use of a further gas to increase the mass of the stream to be expanded in the gas turbine and thereby increase the power that can be produced.

[0048] It will be appreciated that the gaseous nitrogen enriched stream may be withdrawn in gaseous form from the air separation columns or may be withdrawn in liquid form and vaporised against the feed air stream or a nitrogen stream, following an optional pressurisation step.

[0049] The nitrogen stream or the mixed stream (depending whether stream 180 is mixed with the nitrogen enriched streams 21,43 or not) is preferably heated to a temperature of at least 600°C, preferably around 1000°C, in exchanger 19, which may be a pebble heater.

[0050] In Figure 2, the nitrogen stream or the mixed stream (depending whether stream 180 is mixed with the nitrogen enriched streams 21,43 or not) is compressed to a pressure of between 10 and 30 bara in compressor 20, then warmed to ambient temperature and compressed to between 30 and 100 bara in compressor 25 before being warmed to at least 600°C, preferably around 1000°C in exchanger 19. The heated nitrogen stream or mixed stream is sent to turbine 35 or 35' depending whether it is to be sent to the combustion chamber 160 or directly to the expander inlet. Preferably the compressor 25 and turbine 35,35' are coupled.

[0051] In Figure 3, a cryogenic air separation unit 1 comprises a double column with a low pressure column operating in a range of from about 5 to about 10 bar (not shown). The nitrogen enriched stream 3 containing 90mol.% nitrogen produced by the low pressure column is mixed with a further gas, in this case a gaseous carbon dioxide enriched stream 5 containing 90mol.% carbon dioxide at about the same pressure and compressed in compressor 7 to a pressure in a range of from about 15 to about 80 bara. The nitrogen from the high pressure column may also be compressed in compressor 7 and mixed with the carbon dioxide enriched stream.

[0052] Alternatively a nitrogen enriched stream from only the low pressure column or only the high pressure column may be used.

[0053] The double column may be replaced by a single column or a triple column or a system comprising four or more columns. The air separation unit may also comprise an argon column or a mixing column.

[0054] The pure oxygen 9 from the air separation unit 1 is sent to an auto thermal reformer 29 or another type of reformer together with natural gas 11 and steam 13.

[0055] Synthesis gas 15 is removed from the reformer 29 at a temperature of about 1050°C and a pressure in a range of from about 20 to about 80 bar.

[0056] The synthesis gas is cooled against the mixture 17 of principally nitrogen and carbon dioxide compressed in compressor 7 in a heat exchanger 19 which may be a ceramic heat exchanger or a regenerator.

[0057] The synthesis gas is then purified in unit 27 to eliminate the carbon dioxide it contains and at least part of this carbon dioxide is recycled as stream 5 to compressor 7.

[0058] The mixture of carbon dioxide and nitrogen at about 1000°C coming from heat exchanger 19 is expanded in a turbine 21 to produce energy and/ or to drive a compressor of the system such as the compressor of air separation unit 1.

[0059] The carbon dioxide enriched stream 5 may be replaced by an impure argon enriched stream (at least about 2 mol.% argon, preferably at least 30 mol.% argon), an impure oxygen stream (at least 25 mol.% oxygen, preferably at least about 60% oxygen) or an air stream. Alternatively a mixture of any gases containing at least 10% carbon dioxide and/or at least 2% argon and/or at least 25mol.% oxygen and/or air and/or at least 80mol.%nitrogen may be added to the nitrogen enriched stream 3 upstream of the warming step in heat exchanger 19, upstream or downstream of the compressor 7 depending on the pressure at which it is available.

[0060] The argon or oxygen enriched streams may come from air separation unit 1, another air separation unit or another source.

[0061] Preferably the added gases are produced by units consuming a fluid produced by the air separation unit or by the gas turbine

[0062] The additional air may come from the same compressor 2 which compresses air for the air separation unit.

[0063] The mixture of nitrogen and the further gas may be the sole feed to the turbine.

[0064] Alternatively the turbine may be fed by combustion gases from a combustor in addition to the nitrogen mixture.

[0065] The mixture may be heated using sources of heat such as slag from a gasifier, blast furnace gas, gas from the expander of a gas turbine, steam, and the like. In particular the source of heat may be a unit fed by oxygen enriched, argon enriched or nitrogen enriched fluid from the air separation plant which produces a product gas or waste gas at above ambient temperatures and

preferably above 200°C.

[0066] The air compressor 2 may also produce air for a fuel combustor.

[0067] In Figure 4, the nitrogen gas is compressed in two compressors 7,25 to bring it to a pressure between 30 and 100 bars. The heated gas is then expanded in two expanders 35,21.

[0068] In Figure 5, there is shown an air separation unit in which compressed air from compressor 1 is cooled by indirect contact with water in heat exchangers 4,5 before being fed to purification beds 6,7, heat exchanger 9 and then to the air distillation apparatus 10. The water 17 is previously cooled in a cooling tower 16 by direct contact with waste nitrogen 19,20 from the air separation unit 10. Nitrogen enriched stream 19 has been used to regenerate the purification beds 6,7 and consequently contains carbon dioxide. Either stream 19 or stream 20 or both streams 19 and 20 may be sent to the cooling tower 16. This type of cooling apparatus is described in detail in US-A-5505050. At the top of the tower, there is produced a nitrogen stream saturated with water vapour 24 which is mixed with a stream of nitrogen enriched gas 12. In the preferred case where only stream 20 is sent to the cooling tower, the stream 24 will contain between 0 and 10%, preferably between 0 and 2 mol.% oxygen, between 0 and 2 mol.% argon, 0% carbon dioxide and about 5 mol.% water and the rest of the stream is nitrogen.

[0069] The mixed stream 36 is then compressed in compressor 38 and sent to the combustor 160 of a gas turbine. The combustor is also fed with fuel and compressed air 110 from compressor 120.

[0070] Optionally the compressed stream coming from compressor 38 may be heated to an elevated temperature (e.g. above 600°C) before being sent to the gas turbine. The heating may take place as described previously by indirect heat exchange with a waste stream or a stream which requires to be cooled.

[0071] Alternatively, as shown in dashed lines, all or part of the mixed stream may be sent directly to the input of the expander 150.

[0072] Compressor 120 may alternatively supply all or part of the air for the air separation unit.

[0073] Dashed lines 31 on the figures show that other gas streams available on the site such as air, steam and/or gas streams containing at least 20 mol.-% nitrogen, argon, oxygen and/or carbon dioxide may be added at various points of the process.

[0074] Preferably the added gases are produced by units consuming a fluid produced by the air separation unit or by the gas turbine.

[0075] Figure 6 shows a variant of the other figures in which part of the heated nitrogen or heated gaseous mixture is fed back to the inlet of the exchanger 19. This step may take place at the pressure at which the exchange takes place or a lower pressure if compressor 25 and expander 35 are used. It may be necessary to compress the recycled gas if the pressure drop in

exchanger 19 is large. The rest of the heated nitrogen or heated gaseous mixture is sent to a combustion chamber 160 or a turbine 21, 35, 150 as previously described. This feature as mentioned also applies to the case where the nitrogen enriched gas is not mixed with another gas before being sent to the expander.

[0076] The recycle step is necessary in order to avoid too large a temperature difference at one end of the heat exchanger 19. The stream to be recycled may be cooled by various means including a refrigeration unit and/or a heat exchanger permitting heat exchange with a colder fluid, such as natural gas to be used as fuel for the gas turbine.

Claims

1. An integrated air separation apparatus comprising an air separation unit (1,100); means (140) for sending air to the air separation unit, means for sending a nitrogen-enriched gas stream (3) from the air separation unit to a point upstream of an expander (21,150), and means for sending at least one further gas (5,24,31,180) which is air or which contains at least 2 mol.% oxygen, preferably at least 25 mol.% oxygen, and/or at least 2mol.% argon and/or at least 10mol.% carbon dioxide and/or at least 70% nitrogen to the nitrogen-enriched gas stream at a point upstream of the expander, means for mixing the at least one further gas with the nitrogen enriched stream from the air separation unit at a mixing point to form a gaseous mixture and means for sending the mixture upstream of the expander.
2. An apparatus according to claim 1 comprising a heat exchanger (130), means for sending air to the heat exchanger, means for sending air from the heat exchanger to the air separation unit (100), means for sending the nitrogen-enriched gas stream from the air separation unit to the heat exchanger, means for sending nitrogen enriched stream from the heat exchanger to a point upstream of the expander, and means for sending the at least one further gas to the nitrogen-enriched gas stream at a point upstream or downstream of the heat exchanger.
3. An apparatus according to any preceding claim comprising means for sending the gaseous mixture to the input of the expander (21,150).
4. An apparatus according to Claim 3 wherein the expander is a turbine (21).
5. An apparatus according to claims 1 or 2 comprising means for sending the gaseous mixture to an input of a combustor (160) upstream of a gas turbine expander (150) and means for sending the combustion gases from the combustor to the expander
6. An apparatus according to claim 5 comprising means for adding fuel to the gaseous mixture upstream of the combustor.
7. An apparatus according to any preceding claim comprising a compressor (120) for supplying air to the air separation unit (100) and/or to the combustor(160).
8. An apparatus according to any preceding claim comprising respective compressors for compressing air for the combustor (160) and the air separation unit (100).
9. An apparatus according to any preceding claim comprising means (19,130) for warming the nitrogen enriched stream, preferably upstream or downstream of the mixing point.
10. An apparatus according to claim 9 wherein the means for warming the nitrogen enriched stream comprise a heat exchanger (19), and means for sending a gaseous product or waste stream (15) from a plant in which an exothermic process takes place and at least the nitrogen enriched stream to the heat exchanger.
11. An apparatus according to claim 10 comprising means for feeding a gas or liquid (9) produced by the air separation plant or compressed air from a compressor (120) of the installation to the plant (29) in which the exothermic process takes place.
12. An apparatus according to any preceding claim comprising means for feeding a fluid from the air separation unit to a plant (29) from which the further gas (15) is derived.
13. An apparatus according to claim 12 comprising means for sending an oxygen enriched stream (9) from the air separation unit to a reformer (29) and means for deriving a carbon dioxide enriched stream (5) from a gas produced by the reformer and means for sending the carbon dioxide enriched gas to the nitrogen stream.
14. An apparatus according to any preceding claim wherein the at least one further gas (5, 24) which is air or which contains at least 2mol.%oxygen and/or at least 2mol.% argon and/or at least 10mol. % carbon dioxide comes from the air separation unit (1).
15. An integrated power generation system apparatus comprising an air separation unit (100) producing at least one nitrogen-enriched gas stream (21,43), a gas turbine comprising a combustor(160) and an

expander(150), means (120) for sending air to the combustor and to the air separation unit and means for sending a mixture comprising the nitrogen-enriched gas stream from the air separation unit and air to a point upstream of the expander wherein the air mixed with the nitrogen-enriched stream comes from a source other than the means for sending air to the combustor and to the air separation unit.

16. An integrated power generation system apparatus comprising an air separation unit (100) producing a nitrogen-enriched gas stream, a gas turbine comprising a combustor (160) and an expander (150), a heat exchanger (4,5) for cooling air by indirect heat exchange with cooling water (23), means for sending cooled air to the air separation unit, and means for removing at least first and second nitrogen-enriched gas streams (12,19,20) from the air separation unit, a cooling tower (16) for placing in direct contact the first nitrogen enriched gas stream (19,20) and the cooling water upstream of the heat exchanger, means for removing a humidified nitrogen enriched stream (24) from the cooling tower, a compressor (38) for compressing the humidified nitrogen enriched stream and means for sending the humidified nitrogen-enriched gas stream from the compressor unit to a point upstream of the expander (150).
17. The system of Claim 16 wherein the compressed humidified nitrogen-enriched stream is mixed with the second nitrogen-enriched stream (12).
18. The system of Claim 16 or 17 wherein the first nitrogen-enriched stream (20) does not regenerate the purification system (6) of the air separation unit before being sent to the cooling tower (16).
19. A power generation system comprising an air separation unit (1,100), means for sending air to the air separation unit, means for removing a nitrogen enriched stream from the air separation unit and heating it to a temperature above 600°C, means for sending the heated gas to the combustion chamber (160) of a gas turbine or upstream of the expander (150) of a gas turbine.
20. A power generation system according to claim 19 comprising means for compressing the nitrogen enriched stream, preferably to a pressure between 30 and 100 bars upstream the heating means.
21. A power generation system according to claim 19 or 20 comprising means for sending a fluid from the air separation unit to a unit which produces a hot gas stream and means for sending at least part of the hot gas stream (15) to the heating means (19)

so as to heat the nitrogen enriched gas.

22. A power generation system according to claim 19,20 or 21 comprising means for mixing the nitrogen enriched gas with another gas upstream of the heating means (19).
23. A power generation system according to claim 19,20,21 or 22 comprising means for expanding the heated nitrogen enriched gas stream upstream of the combustion chamber or of the expander.
24. An integrated air separation process using an air separation unit (1,100) and an expander (21,150), comprising the steps of sending air to the air separation unit, sending a nitrogen enriched stream from the air separation unit to a point upstream of the expander, and sending at least one further gas stream (5,24,31,180) other than a fuel stream to a point upstream of the expander to form a mixture.
25. A process according to Claim 24 wherein at least one further gas is air.
26. A process according to Claim 24 or 25 wherein at least one further gas (5,24,31,180) contains at least 2mol.% oxygen, preferably 25 mol.% oxygen and/or at least 2mol.% argon and/or at least 10mol.% carbon dioxide.
27. A process according to Claim 26 wherein at least one further gas (5,24,108) contains at least 70mol.% oxygen and/or at least 30mol.% argon and/or at least 90mol.% carbon dioxide.
28. A process according to Claim 27 wherein at least one further gas contains at least 80mol.% oxygen or at least 80mol.% argon or at least 95mol.% carbon dioxide.
29. A process according to any of claims 24 to 28 comprising mixing the further gas with the nitrogen enriched stream from the air separation unit to form a gaseous mixture.
30. A process according to any of claims 24 to 29 comprising sending the gaseous mixture to the input of the expander (21).
31. A process according to any of claims 24 to 30 comprising sending the gaseous mixture to the input of a combustor (160) of an expander (150) of a gas turbine.
32. A process according to any of claims 24 to 31 comprising removing said further gas (5,24,31,180) comprising at least 25 mol.-% oxygen and/or at least 2mol.% argon and/or at least 10% carbon

dioxide from the air separation unit.

exchanger (19).

33. A process according to any of claims 29 or 30 to 32 when dependent on claim 29 wherein the enriched nitrogen stream is warmed either before or after the mixing step to a temperature of at least ambient temperature, preferably at least 600°C before being sent to the point upstream of the expander by indirect heat exchange with a gaseous stream which is a product or a waste stream.
34. The process of claim 33 wherein the gaseous stream is produced by a unit fed by an oxygen-enriched stream or a nitrogen enriched stream or an argon enriched stream from the air separation unit (1,100) or by a compressed air stream from a compressor (120) which also feeds air to the air separation unit.
35. An integrated power generation process comprising cooling air by indirect heat exchange with cooling water in a heat exchanger (4,5), sending cooled air to the air separation unit, separating the air in the air separation unit, removing at least a first nitrogen-enriched gas stream (19,20) from the air separation unit, placing in direct contact in a cooling tower (16) the first nitrogen enriched gas stream and the cooling water (23) to be sent to the heat exchanger, removing a humidified nitrogen enriched stream (24) from the cooling tower, compressing the humidified nitrogen enriched stream in a compressor unit (38), sending the humidified nitrogen-enriched gas stream from the compressor unit to a point upstream of an expander (150) of a gas turbine, sending an oxygen containing fluid (110) and fuel to a combustor (160) of the gas turbine to produce combustion gases and sending combustion gases from the combustor to be expanded in the expander.
36. An integrated power generation process comprising sending air to an air separation unit (100), removing a nitrogen-enriched stream (21,24,43) from the air separation unit, heating the nitrogen enriched stream to at least 600°C by indirect heat exchange in a heat exchanger (19) and sending the heated nitrogen enriched stream either to the combustion chamber (160) of a gas turbine or upstream of the expander (150) of a gas turbine.
37. The system of Claim 36 in which the nitrogen enriched stream is expanded between the heating step and the combustion chamber or the inlet of the expander.
38. The system of Claim 36 or 37 in which the nitrogen enriched stream is compressed to a pressure between 30 and 100 bars upstream of the heat
39. The system of any of Claims 36 to 38 in which the nitrogen enriched stream is mixed with another stream (31,180) upstream or downstream of the heat exchanger (19).

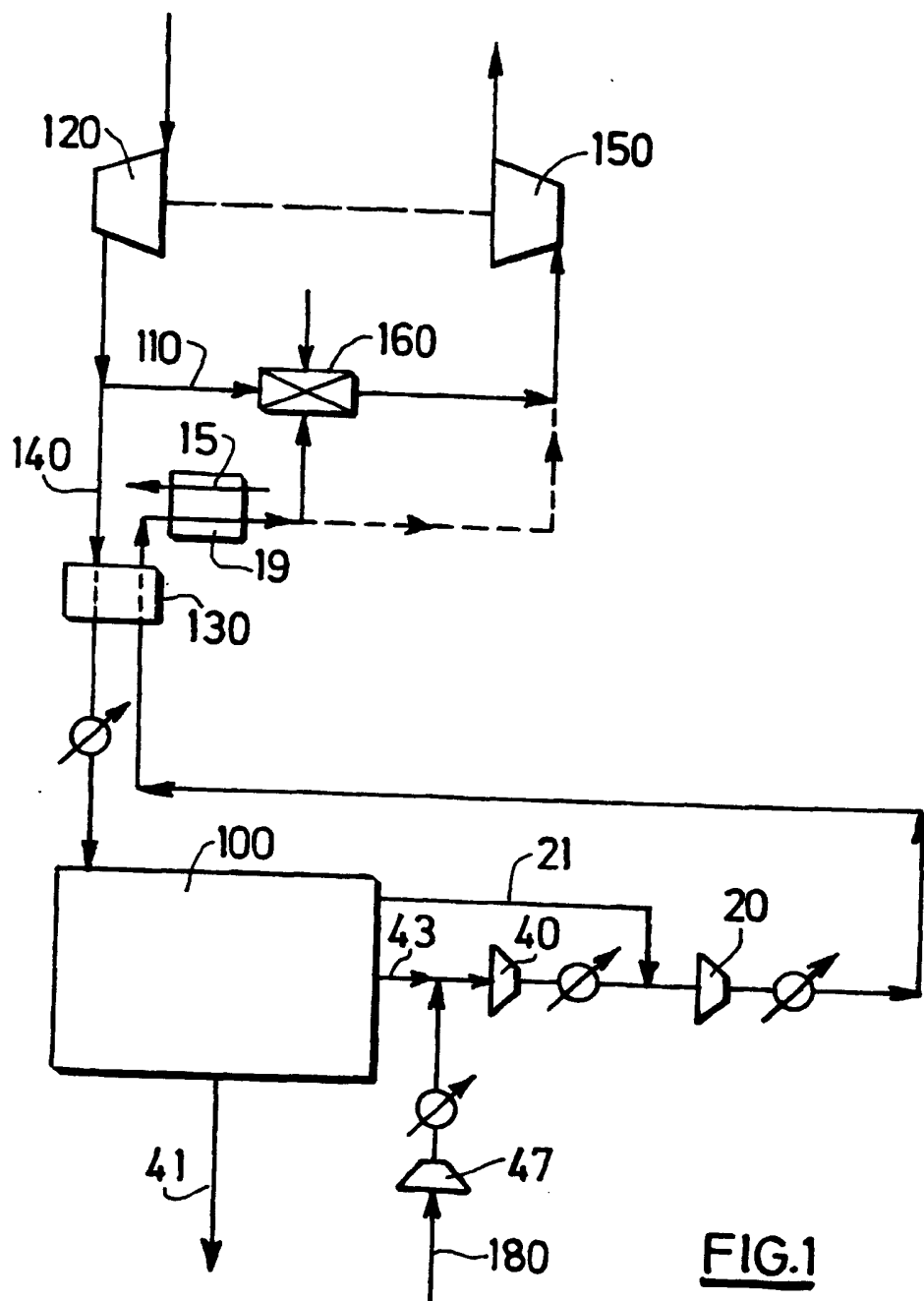


FIG.1

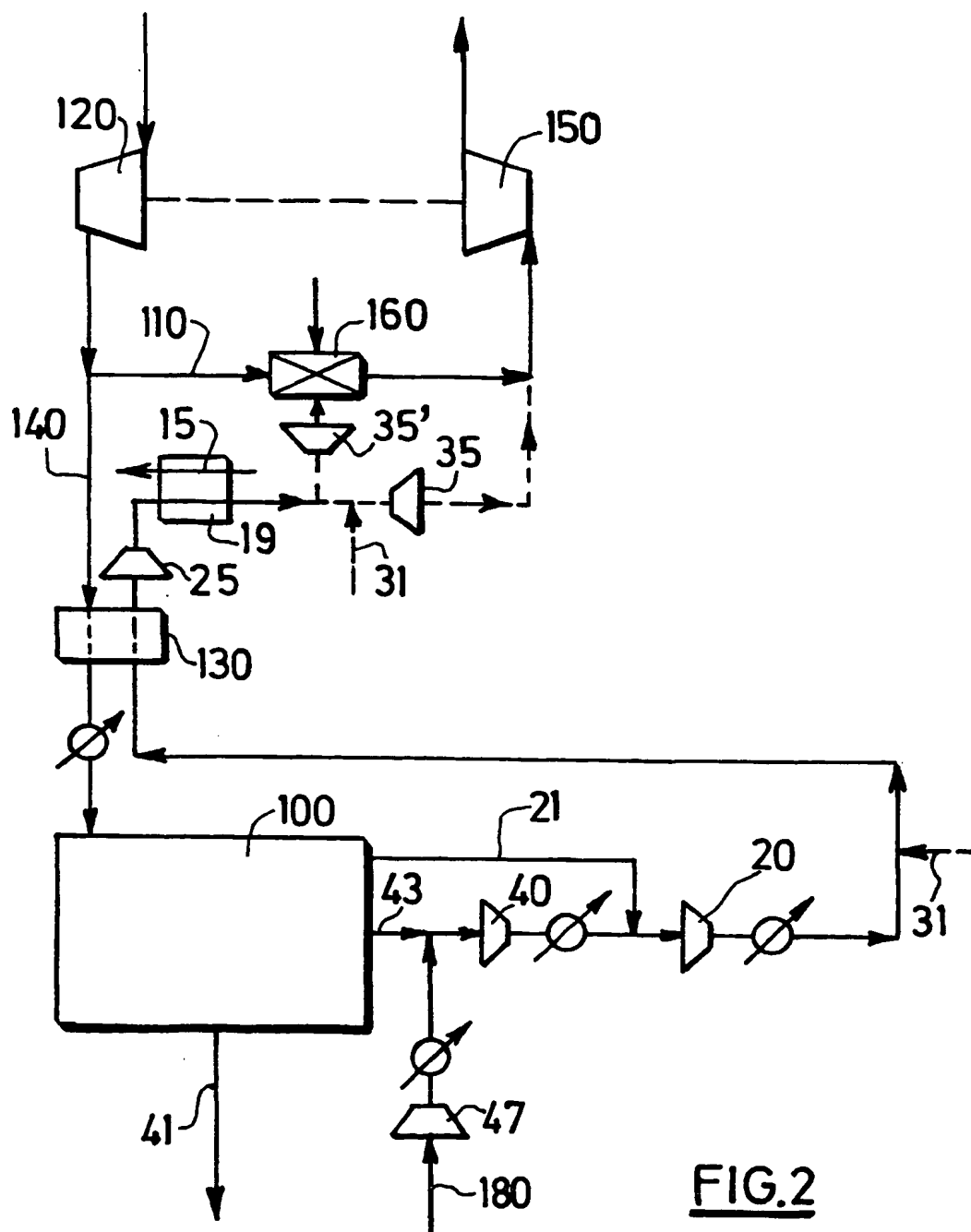


FIG.2

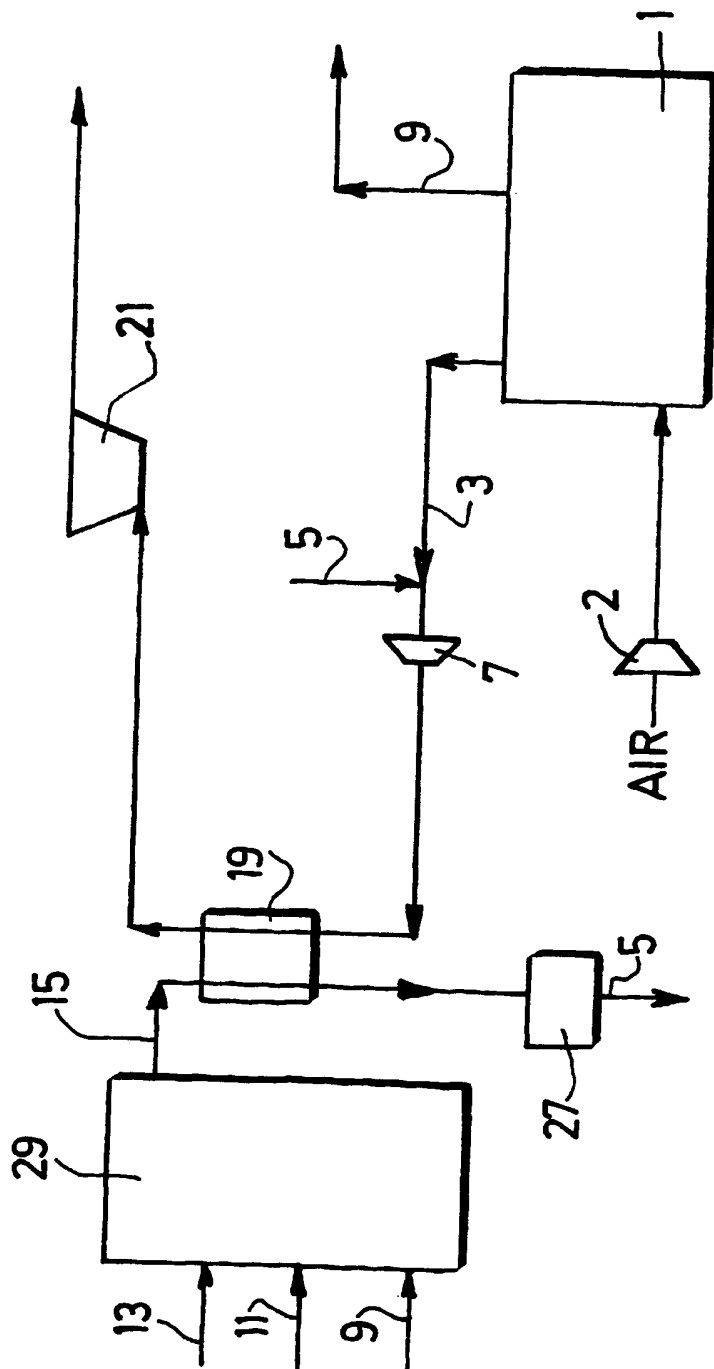


FIG.3

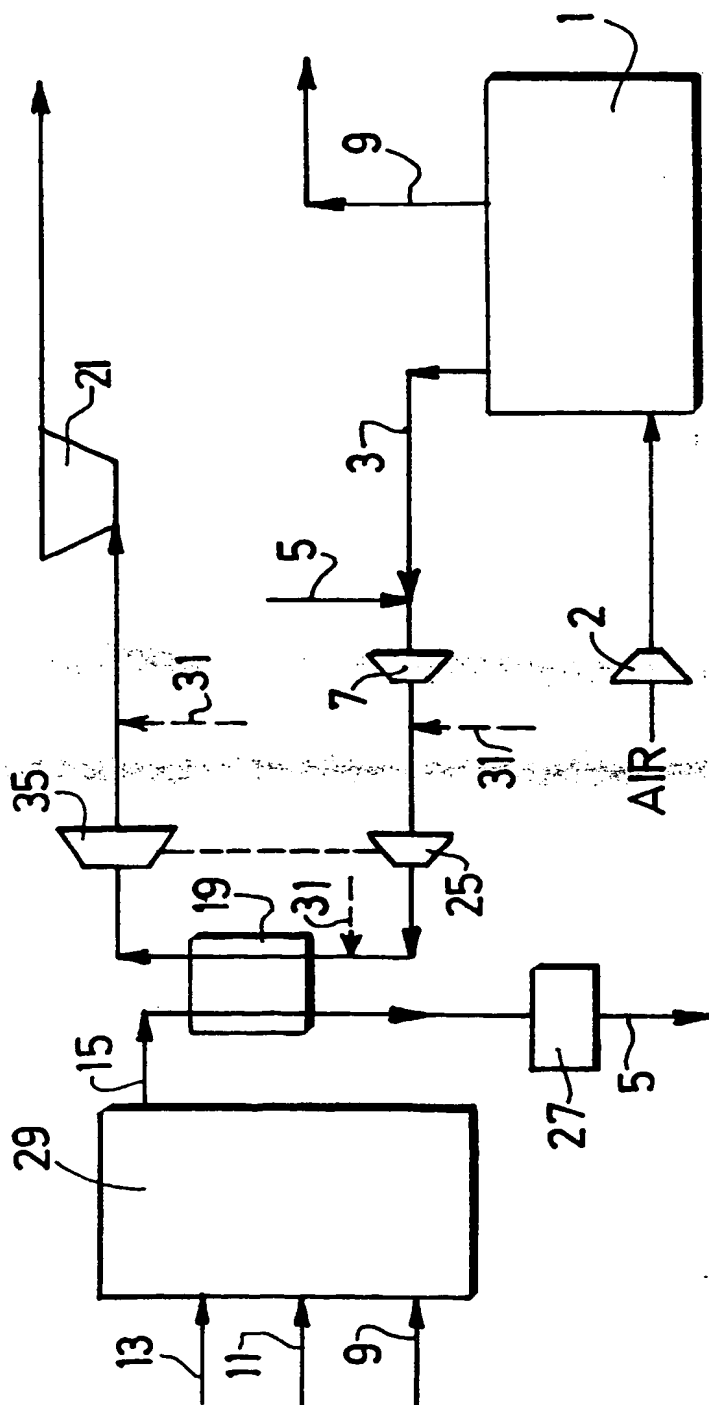


FIG. 4

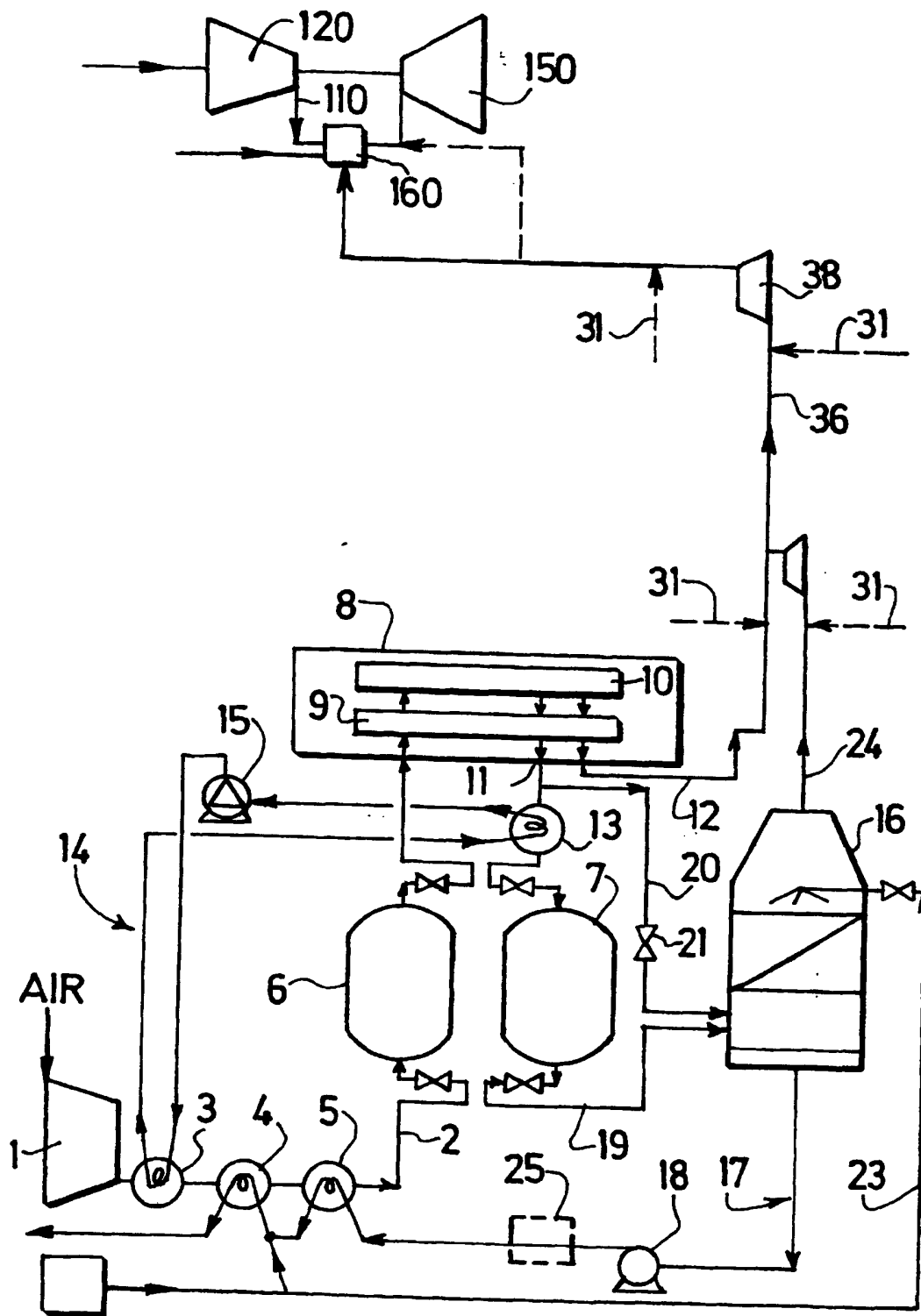


FIG.5

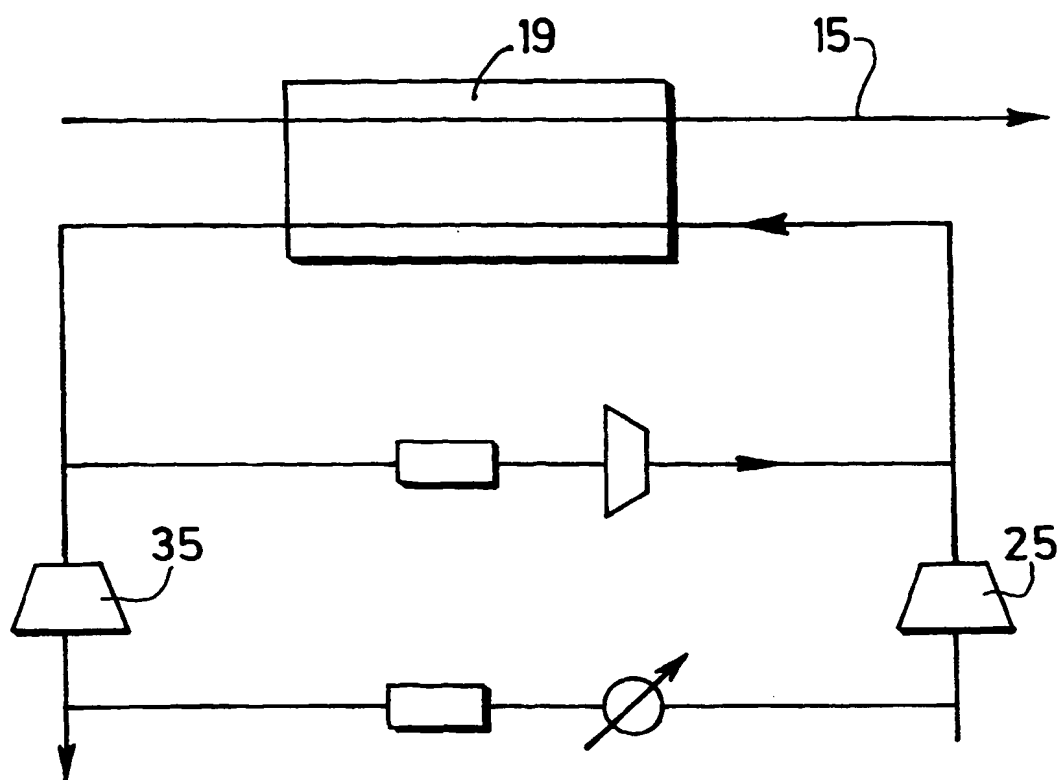
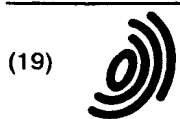


FIG.6

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(11)

EP 1 043 557 A3

(12)

EUROPEAN PATENT APPLICATION

(88) Date of publication A3:
25.04.2001 Bulletin 2001/17

(51) Int. Cl.⁷: **F25J 3/04**

(43) Date of publication A2:
11.10.2000 Bulletin 2000/41

(21) Application number: **00201097.3**

(22) Date of filing: **24.03.2000**

(84) Designated Contracting States:
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE**
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **09.04.1999 US 289286**
20.12.1999 US 466972

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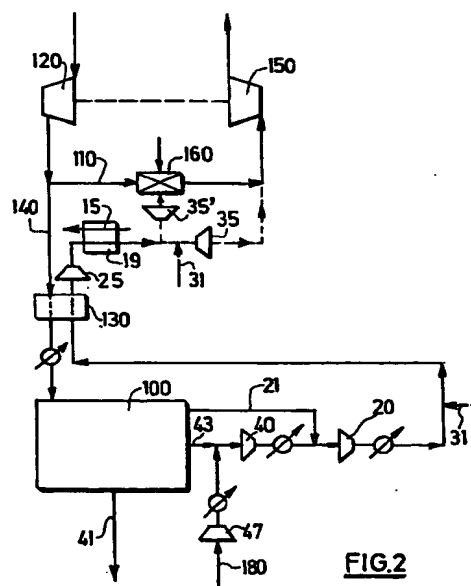
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(54) Integrated air separation plant and power generation system

(57) In an air separation plant (1) integrated with another process, work is recovered from a nitrogen enriched stream (3) produced by an air separation process either by expanding the nitrogen enriched stream directly in a turbine (21,150) or by combustion of the nitrogen enriched stream with a fuel stream and expanding gas produced by the combustion. The work produced by the expansion is maximised by mixing the nitrogen enriched stream before the expansion step with a further gas stream (5,31) which may contain at least 2mol.% oxygen and/or at least 2mol.% argon and/or at least 10mol.% carbon dioxide.



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EUROPEAN SEARCH REPORT

Application Number
EP 00 20 1097

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Place of search THE HAGUE		Date of completion of the search 27 February 2001	Examiner Lapeyrere, J
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EPO FORM 1503 03.92 (P04C01)



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Application Number
EP 00 20 1097

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CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 (03.92) (P4/C01)



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Application Number
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Application Number
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CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

- ☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):
- ☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

- ☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.
- ☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.
- ☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:
- ☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

European Patent
OfficeLACK OF UNITY OF INVENTION
SHEET BApplication Number
EP 00 20 1097

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. Claims: 1-15,

17 (as far as related to mixing N2 with a further gas),

22 (as far as related to mixing N2 with further gas), 24-32, 33 (as far as dependant to claim 24),

34 (as far as dependant to claim 24),

39 (as far as related to mixing N2 with a further gas)

Installation for cryogenic air separation wherein nitrogen is produced and mixed with one further gas.

2. Claims: 16, 17 (as far as dependant on claim 16), 18, 35

Installation for cryogenic air separation wherein a nitrogen stream is cooled in a cooling tower.

3. Claims: 19-21, 22 (as far as dependant on claim 19), 23, 33 (as far as related to heating N2 to 600 C), 34 (as far as related to heating N2 to 600 C), 36-38, 39 (as far as dependant on claim 36)

Installation for cryogenic air separation wherein a nitrogen stream is heated to at least 600 C.

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EP 00 20 1097

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